as a semiconductor wafer having a device pattern thereon to a flat mirror finish by bringing the surface of the workpiece into contact with a surface of the polishing cloth.

Description of the Prior Art:

Recent rapid progress in semiconductor device integration demands smaller and smaller wiring patterns or interconnections and also narrower spaces between interconnections which connect active areas. One of the processes available for forming such interconnections is photolithography. Though the photolithographic process can form interconnections that are at photolithographic process can form interconnections that are at most 0.5 μm wide, it requires that surfaces on which pattern images are to be focused by a stepper be as flat as possible because the depth of focus of the optical system is relatively small.

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It is therefore necessary to make the surfaces of semiconductor wafers flat for photolithography. One customary way of flattening the surfaces of semiconductor wafers is to polish them with a polishing apparatus, and such a process is called Chemical Mechanical Polishing (CMP). In CMP the semiconductor wafers are chemically and mechanically polished while supplying an abrasive liquid comprising abrasive grains and a chemical solution such as an alkaline solution.

Please replace the paragraphs beginning at page 2, line 18, to page 3, line 14, with the following rewritten paragraphs:

However, the recent higher integration of IC or LSI demands a more and more planarized finish of the semiconductor wafer. In order to satisfy such a demand, harder materials, such as polyurethane foam, have been recently used as the polishing cloth. After, for example, one or more semiconductor wafers have been polished by bringing the semiconductor wafer into sliding contact with the polishing cloth and rotating the turntable, abrasive grains in the abrasive liquid or ground-off particles of the semiconductor wafer are attached to the polishing cloth. In the case of the nonwoven fabric cloth, the polishing cloth is napped. In the case where the semiconductor wafers are repeatedly polished by the same polishing cloth, the polishing performance of the polishing cloth is degraded, thus lowering the polishing rate and causing a nonuniform polishing

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action. Therefore, after polishing a semiconductor wafer or during polishing of a semiconductor wafer, the polishing cloth is processed to recover its original polishing capability by a dressing process.

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For a dressing process for recovering the polishing capability of the polishing cloth made of relatively hard material such as polyurethane foam, there has been proposed a dresser having diamond grains. This dressing process using the diamond grain dresser is effective in restoring the polishing capability of the polishing cloth and tends not to rapidly lower the polishing rate thereof.

Please replace the paragraphs beginning at page 4, line 1, to page 5, line 24, with the following rewritten paragraphs:

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Conventionally, the polishing apparatus having a diamond grain dresser comprises a top ring for holding the semiconductor wafer and pressing the semiconductor wafer against a polishing cloth on a turntable, and a dresser for dressing the surface of the polishing cloth, the top ring and the dressing being supported by respective heads. The dresser is connected to a motor provided on the dresser head. The dresser is pressed against the surface of the polishing cloth while the dresser is rotated about its central axis and the dresser head is swung, thereby dressing a certain area of the polishing cloth which is to be used for polishing. That is, the dressing of the polishing cloth is preformed by rotating the turntable, pressing the rotating dresser against the polishing cloth, and moving the dresser radially of the polishing cloth by swinging the dresser head. In the conventional dressing process, the rotational speed of the dresser is equal to the rotational speed of the turntable.

However, when the polishing cloth is dressed by the diamond grain dresser, the polishing cloth is slightly scraped off. Unless the polishing cloth is uniformly scraped off in any vertical cross section, i.e., is uniformly scraped off in a radial direction of the polishing cloth, the semiconductor wafer, which is a workpiece to be polished, cannot be uniformly polished as the number of dressing processes increases. It is confirmed by the inventors of the present application that when the dressing is performed in such a manner that the rotational speed of the dresser is equal to the rotational speed of the turntable, the amount of material removed from the inner

circumferential region of the polishing cloth is greater than the amount of material removed from the outer circumferential region of the polishing cloth.

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FIG. 6 shows measurements of the removal amount of material in the polishing cloth which has been dressed by the conventional dressing method. In FIG. 6, the horizontal axis represents a distance from a center of rotation, i.e., a radius (cm) of the polishing cloth, and the vertical axis represents the amount of material removed from the polishing cloth, which is expressed by a removal thickness (mm) of material. FIG. 6 shows measurements of the removal thickness were the same and about 500 semiconductor wafers were polished on the polishing cloth and the corresponding number of dressing processes were applied to the polishing cloth. Two kinds of diamond grain sizes were used in the experiment. For example, the rotational speed of the turntable was 13 rpm, the rotational speed of the dresser was 13 rpm, 500 semiconductor wafers were polished on the polishing cloth made of polyurethane foam, and a corresponding number of the dressing processes were applied to the polishing cloth. In this case, the difference in a removal thickness of material between the outer circumferential region and the inner circumferential region of the polishing cloth was about 100 μm.

Please replace the paragraphs beginning at page 6, line 3, to page 7, line 11, with the following rewritten paragraphs:

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According to one aspect of the present invention, there is provided a method of dressing a polishing cloth mounted on a turntable by bringing a dresser into contact with the polishing cloth, comprising measuring heights of a surface of the polishing cloth at radial positions of the polishing cloth in a radial direction thereof, determining a rotational speed of the dresser with respect to a rotational speed of the turntable on the basis of the measured heights, and dressing the polishing cloth by pressing the dresser against the polishing cloth while the turntable and the dresser are rotating.

According to another aspect of the present invention, there is provided a method of dressing a polishing cloth mounted on a turntable by bringing a dresser in contact with the polishing cloth, comprising setting a rotational speed of the dresser with respect to a rotational speed of the turntable

speed of the turntable so that the rotational speed of the dresser is lower than the rotational speed of the turntable and dressing the polishing cloth by pressing the dresser against he polishing cloth while the turntable and the dresser are rotating.

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According to still another aspect of the present invention, there is provided an apparatus for dressing a polishing cloth mounted on a turntable, comprising a dresser for contacting the polishing cloth, an actuator for rotating the dresser about a central axis of the dresser, and a measuring device for measuring heights of a surface of the polishing cloth at radial positions of the polishing cloth in a radial direction thereof. A rotational sped of the dresser with respect to a rotational speed of the turntable is determined on the basis of the measured heights, and the polishing cloth is dressed by pressing the dresser against the polishing cloth while the turntable and the dresser are rotating.

The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings, which illustrate a preferred embodiment of the present invention by way of example.

Please replace the paragraphs beginning at page 10, line 16, to page 11, line 6, with the following rewritten paragraphs:

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The polishing apparatus operates as follows. The semiconductor wafer 2 is held on the lower surface of the top ring 3, and is pressed against the polishing cloth 4 on the upper surface of the turntable 20. The turntable 20 and the top ring 3 are rotated relatively to each other to thereby bring the lower surface of the semiconductor wafer 2 in sliding contact with the polishing cloth 4. At this time, the abrasive liquid nozzle 5 supplies the abrasive liquid to the polishing cloth 4. The lower surface of the semiconductor wafer 2 is now polished by a combination of a mechanical polishing action of abrasive grains in the abrasive liquid and a chemical polishing action of an alkaline solution in the abrasive liquid.

The polishing process comes to an end when the semiconductor wafer 2 is polished to a predetermined thickness of a surface layer thereof. When the polishing process is finished, the

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polishing properties of the polishing cloth 4 have been changed and the polishing performance of the polishing cloth 4 deteriorates. Therefore, the polishing cloth 4 is dressed to restore its polishing properties.

Please replace the paragraphs beginning at page 11, line 22, to page 12, line 15, with the following rewritten paragraphs:

One example of the dresser 10 is as follows. The dresser body 11 has a diameter of 250 mm. The annular diamond grain layer 13, having a width of 6 mm, is formed on the circumferential area of the lower surface of the dresser body 11. The annular diamond grain layer 13 comprises a plurality of sectors (eight in this embodiment). The diameter of the dresser body 11 is larger than the diameter of the semiconductor wafer 2, which is a workpiece to be polished. Thus, the dressed surface of the polishing cloth has margins at inner and outer circumferential regions with respect to the surface of the semiconductor wafer being polished.

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The polishing cloth is dressed by the dresser in a manner shown in FIG. 3. The polishing cloth 4 made of polyurethane foam to be dressed is attached to the upper surface of the turntable 20, which rotates in a direction indicated by the arrow A. The dresser 10, which rotates in a direction indicated the by the arrow B, is pressed against the polishing cloth so that the annular diamond grain layer 13 is brought in contact with rotated relative to each other to thereby bring the lower surface of the diamond grain layer 13 in sliding contact with the polishing cloth 4. In this case, the dresser is not swung.

Please replace the paragraphs beginning at page 12, line 23, to page 13, line 11, with the following rewritten paragraphs:

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In the embodiments of dressing processes described below, the rotational speed ratios of the turntable to the dresser are 20rpm:12rpm, 50rpm:30rpm, and 150rpm:90rpm, which are each set to a ratio of 1:0.6.

FIG. 4 is a graph showing measurements of the removal thickness of material in the polishing cloth which has been dressed according to the embodiment of the present invention. In

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FIG. 4, the horizontal axis represents a radial position on the polishing cloth (cm), and the vertical axis represents a removal thickness (mm) of material from the polishing cloth. L_T represents the area where the dresser contacts the polishing cloth. The dresser 10 is pressed against the polishing cloth 4 at a pressure of 450 gf/cm^2. As described above, the dressing area (L_T) is larger than the area (L_D) where the semiconductor wafer to be polished contacts the polishing cloth to provide margins at inner and outer circumferential regions of the polishing cloth in a radial direction thereof.

Please replace the paragraphs beginning at page 14, line 27, to page 17, line 16, with the following ~~rewritten paragraphs:~~

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Next, the theory in which the removal thickness of material from the polishing cloth is substantially uniform from the inner circumferential region to the outer circumferential region of the polishing cloth by setting the rotational speed ratio of the turntable to the dresser to a range of 1:0.4 to 1:0.85 will be described. This theory is based on the assumption that the relative velocity between the dresser and the polishing cloth affects the amount of material removed from the polishing cloth, and the amount of material removed from the polishing cloth is greater as the relative velocity is larger.

FIGS. 5A, 5B and 5C show the distribution of relative velocity vectors between the polishing cloth and the dresser. The center (O) of the turntable is located at the left side of the dresser. FIG. 5A shows a verification example in which the rotational speed of the turntable is 100 rpm and the rotational speed of the dresser is 50 rpm. FIG. 5B shows a verification example in which the rotational speeds of the turntable and the dresser are 100 rpm, respectively. FIG. 5C shows a verification example in which the rotational speed of the turntable is 100 rpm and the rotational speed of the dresser is 150 rpm, i.e., the rotational speed of the dresser is higher than that of the turntable. In FIGS. 5A, 5B and 5C, "O" represents a center of the turntable 20 and a number of arrows in the annular diamond grain layer 13 of the dresser 10 represents relative velocity vectors, which are vectors of relative velocities between the diamond grain layer 13 and the polishing cloth 4 at respective positions. As the absolute value of the relative velocity vector

is larger, the removal thickness of material from the polishing cloth is greater at the position concerned. As in the conventional method, when the rotational speed of the dresser is equal to the rotational speed of the turntable, the relative velocity vectors are uniform in all areas which are dressed by the dresser 10 as shown in FIG. 5B. In this condition, the removal thickness of material from the polishing cloth is greater at the inner circumferential region of the polishing cloth, which is nearer to the center (O) of the turntable, and the removal thickness of material from the polishing cloth is smaller at the outer circumferential region, which is farther away from the center (O) of the turntable. Therefore, in order to correct nonuniform tendency of the removal thickness of material from the polishing cloth, it is desirable that the relative velocity be higher at the outer circumferential region, which is farther away from the center (O) of the turntable, and the relative velocity be lower at the inner circumferential region, which is nearer to the center (O) of the turntable.

As shown in FIG. 5A, when the rotational speed of the dresser is lower than the rotational speed of the turntable, the relative velocity is lower at the inner circumferential region, which is nearer to the center (O) of the turntable, and is higher at the outer circumferential region, which is farther away from the center (O) of the turntable. Therefore, the removal thickness of material from the polishing cloth is smaller at the inner circumferential region of the polishing cloth and is greater at the outer circumferential region of the polishing cloth, because as the absolute value of the relative velocity vector is larger, the removal thickness of material from the polishing cloth is greater at the position concerned.

On the other hand, in the case where the rotational speed of the turntable is equal to the rotational speed of the dresser, the relative velocity vectors are uniform at all positions as shown in FIG. 5B. In this case, as shown in FIGS. 6, the removal thickness of material from the polishing cloth is greater at the inner circumferential region of the polishing cloth and is smaller at the outer circumferential region thereof. Therefore, by combination of the tendency shown in FIG. 6 and the tendency shown in FIG. 5A, in which the relative velocity is higher at the outer circumferential region of the polishing cloth, i.e., by making the rotational speed of the dresser lower than the rotational speed of the turntable, the removal thickness of material from the

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polishing cloth is substantially uniform at all radial positions of the polishing cloth in a radial direction thereof.

Please replace the paragraph beginning at page 18, line 8, to line 24, with the following rewritten paragraph:

As shown in FIG. 7, the rotation of the turntable 20 is stopped, the contact 26 contacts the surface of the polishing cloth 4, and the dresser head 21 is swung about the rotating shaft 22 by rotating the rotating shaft 22 about its won axis. Thus, as shown in FIG. 8, the contact 26 is moved radially while it contacts the surface of the polishing cloth 4, and the heights at radial positions of the polishing cloth in a radial direction thereof are measured during movement of the contact 26. That is, the surface contour, i.e., the undulation of the surface of the polishing cloth 4 in a radial direction thereof, is measured. Since the dressing liquid such as water remains on the surface of the polishing cloth 4 in a radial direction thereof, is measured. Since the dressing liquid such as water remains on the surface of the polishing cloth 4, the contact type of sensor is desirable to measure the surface contour, rather than a noncontact type of sensor, when measuring the undulation of the surface of the polishing cloth. Next, the process for using the dressing apparatus shown in FIGS. 7 and 8 will be described below with reference to FIG. 9.

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Please replace the paragraphs beginning at page 19, line 23, to page 20, line 28, with the following rewritten paragraphs:

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Next, in step 6, the measured values obtained in step 5 are subtracted from the initial values obtained in step 1 to obtain the removal thickness of material from the polishing cloth at radial positions of the polishing cloth in a radial direction thereof. FIG. 11 shows the removal thickness of material from the polishing cloth at radial positions of the polishing cloth in a radial direction thereof. In FIG. 11, the horizontal axis represents the radius (mm) of the polishing cloth, and the vertical axis represents the removal thickness of material from the polishing cloth. In FIG. 11, the curve D shows the removal thickness of material at radial positions of the polishing cloth in a radial direction thereof when the rotational speed ratio of the turntable to the dresser is 1:0.5. The curve E shows the removal thickness of material at radial position of the

polishing cloth in a radial direction thereof when the rotational speed ratio of the turntable to the dresser is 1:0.7.

Next, in step 7, the obtained curve, such as the curve D or E, is compared with the preset desired surface of the polishing cloth. If the removal thickness of material from the polishing cloth is greater at the inner circumferential region than at the outer circumferential region, the rotational speed of the dresser 10 is lowered in step 8. If the removal thickness of material from the polishing cloth is in an allowable range at the inner and outer circumferential regions, the rotational speed of the dresser 10 is not changed in step 9. If the removal thickness of material from the polishing cloth is greater at the outer circumferential region than at the inner circumferential region, the rotational speed of the dresser 10 is increased in step 10. In steps 8 through 10, the rotational speed of the turntable is not changed. After setting the rotational speed of the dresser 10 to an optimum value in steps 8 through 10, a next dressing process is performed by the set value of the rotational speed of the dresser 10.

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Please replace the paragraphs beginning at page 21, line 28, to page 22, line 22, with the following rewritten paragraphs:

In the embodiments, although the annular diamond grain layer and the annular SiC layer have a circular outer shape and a circular inner shape, respectively, they may have an elliptical outer shape and an elliptical inner shape, respectively, or a circular outer shape and a heart-shaped inner shape, or any other shapes. Further, the dresser may have a solid circular diamond layer or a solid circular SiC layer without having a hollow portion. The dresser may also comprise a dresser body, and a plurality of small circular contacting portions made of diamond grains and arranged in a circular array on the dresser body.

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As is apparent from the above description, the present invention offers the following advantages.

Since the heights of the surface of the polishing cloth at radial positions of the polishing cloth in a radial direction thereof are measured, the rotational speed of the dresser relative to the rotational speed of the turntable is determined on the basis of the measured values, and a dressing

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process is performed in the determined rotational speed ratio of the turntable to the dresser. The polishing cloth is thus uniformly dressed in a radial direction to have a desired surface contour from the inner circumferential region to the outer circumferential region thereof.

IN THE ABSTRACT

Please replace the original abstract with the enclosed substitute abstract.

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